# EXPERIMENTS AND INVESTIGATIONS



CONDUCTED AT THE

# PENNSYLVANIA

# STATE COLLEGE,

1881-2.

By Prof. W. H. JORDAN,
*Pennsylvania State College.*

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## Effect of Period of Cutting and of the Soil upon the Composition of Timothy Hay.

It is generally understood that hay varies in composition, and consequently in value, according to the conditions under which it is grown, and the time at which it is cut. Very much has been learned concerning the nature and causes of such variations, and of their effect upon the nutritive value of hay ; but we are still far from possessing the necessary amount of information on some points. To aid in securing the desired knowledge was the aim of this investigation. What is given in the following pages is simply a report of progress, as other samples of hay are to be analyzed. Of course all such work has for its object a better understanding of how to secure the maximum nutritive value in the grass or hay used for feeding, and in order that the utility of the analyses herewith reported, and of those to follow, may be seen, there is given a brief statement of some of the main facts concerning the ingredients of cattle foods, and their relation to animal nutrition, followed by a resumé of present knowledge pertaining to the main points under consideration.

### The Ingredients of Plants and their Office in Animal Nutrition.

All vegetable cattle foods are made up of four classes of substances, viz : *Nitrogenous organic substances*, (included, heretofore, under the general names of *albuminoids* or *protein*,) *carbo-hydrates*, *fats* or *oils*, and *mineral substances*, and the value of any given food stuff depends upon the relative percentage which it contains of these different ingredients. An animal grows, exercises muscular force, produces milk and young, and keeps up a supply of bodily heat, and these different food elements furnish the means whereby this is done. Moreover, each of these different classes of substances has its own peculiar part to play in maintaining animal life. One class may be able to do what another cannot.

Protein or Albuminoids.—These terms, sometimes one and sometimes the other, have been used to designate the organic nitrogenous constituents of plants as a class. It has been assumed, until lately, that essentially all of the nitrogen of plants is combined to form true albuminoids, compounds of which muscular tissue, (lean meat,) the white of an egg, the flesh of

* For the plans of the experiments and investigations herewith reported, and for the accompanying analyses, I am responsible. For the careful and patient supervision necessary to the successful prosecution of experimental work, credit belongs to the superintendents of the Central and Eastern Experimental Farms, Mr. W. C. Patterson and Mr. J. F. Hickman. The work was undertaken and will be continued in the hope that some conclusions will be reached that will prove to be of advantage to the farmer as a producer. The results here reported may serve possibly to give some idea of what might be accomplished by a well equipped experiment station, where land, means, and men should be centralized in one efficient organization.

It is but fair to say that the analytical work has been possible through the great progress that has been made in the development at the College of a working chemical laboratory within the past few years, so that analyses can now be executed with tolerable rapidity and according to modern methods.

W. H. Jordan.

fishes, and the gluten of wheat are good examples. It is now known that a portion of the nitrogen may be combined to form compounds not albuminoid in their character, and to this latter class has been given the term *amides*. As special interest attaches to the occurrence and properties of these compounds, they will receive fuller mention later. The albuminoids proper are considered to be the most important ingredients of cattle foods. From them alone can be produced the muscular tissue of the animal body, as well as the casein and albumen of milk. Butter fat is, undoubtedly, formed from them, and a portion of the body fat, and muscular force is somehow dependent upon their presence in the food.

While the most important nutritive offices of albuminoids are indicated above, they probably, at all times, directly aid in keeping the animal warm, and in case the ration is composed entirely of albuminoids, can be made to furnish all the fuel for the maintenance of bodily heat. In short, there is nothing these compounds cannot do in sustaining life, unless it be the supplying of mineral substances. After having gone through the digestive processes, the products of their decomposition make up quite a portion of the fertilizing value of farm manures.

*Carbo-hydrates* includes such compounds as crude fiber (cellulose and lignose,) starch, sugar, gums, &c. These bodies contain no nitrogen, and, therefore, cannot serve as the source of flesh or the principal compounds of milk. Just what their relation is to muscular force is not yet fully determined. Their chief office seems to be to supply fuel for keeping up animal heat, though they undoubtedly aid in the formation of fat in the herbivora, but not in the carnivora.

The *fats* serve the purpose of storing animal fat, and are also burned to keep the animals warm, one pound of fat being worth, for fat and heat-forming purposes, probably not far from two pounds of starch or sugar.

The percentages of fat, as given in fodder tables, are too large, owing to the fact that the ether used in extracting them dissolves out other substances. Both the fats and carbo-hydrates have an indirect value in that they serve to protect the albuminoids from destruction, and thus make greater flesh or milk production possible.

**Influence of Fertility.**

Fodder manufactured from the same species of plant does not generally have the same composition in two cases where there has been a difference in the conditions of growth and treatment. Past investigations seem to indicate that *the state of fertility of the soil* has a prominent influence in determining not only the quantity, but the quality of farm crops. Shlœsing* found that the ash of tobacco varied greatly in composition, according to the fertilizer applied. It is a well-known fact that the percentage of sugar in sugar beets can be diminished or increased according to the method of manuring.

Ritthausen and Pott, † Krensler and Kern,‡ and especially Lawes and Gilbert, have found that the application of an abundance of nitrogenous manures to wheat, causes an increased percentage of nitrogen in the grain. Emmerling§ found that hay grown upon low land of good quality contained nearly two per cent. more of protein than hay grown upon poor land of the same general character.

Dr. Armsby¶ cites analyses of two samples of hay, one being taken "from

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* Jahresbericht der Agr., Chem. III., p. 81.
† Ibid. XVI. I. p. 304.
‡ Ibid. XVIII, I, p. 253.
§ Ibid., p. 269.
¶ Manual of Cattle Feeding, pp. 289–290.

a part of the field which was in an ordinary state of fertility," and the other "from spots where the excrement and urine of the grazing animals had caused an especial luxuriant growth." The former contained only eleven per cent. of protein, the latter over twenty per cent.

There is found to be quite a difference between American and German hays, the latter being the better. Below is a comparison of the average composition of nine (9) samples of American timothy with the composition of German timothy:

| | Water. | Protein. | Fiber. | Nitrogen, free extractive matters. | Fat. |
|---|---|---|---|---|---|
| | Per cent. | Per cent. | Per cent. | Per cent. | Per cent. |
| American timothy, . . . . . . | 13.50 | 6.16 | 28.94 | 45.85 | 1.68 |
| German timothy, . . . . . . . . | 14.3 | 9.7 | 22.7 | 45.8 | 3.0 |

It is not improbable that the difference seen above is due to the more thorough cultivation practiced in Germany, although a partial cause may be found in climatic conditions.

#### Influence of the Stage of Growth.

Hay made from early cut grass differs from that made from late cut, in the following particulars:

1. It contains a larger percentage of nitrogen. Whether this is due to the presence of a greater percentage of albuminoids or not will be discussed later.
2. It contains a smaller percentage of crude fiber.
3. It contains larger percentages of fat and of ash.
4. One effect of the above differences in the composition of early and late cut hay, is to render the former more digestible, which is certainly in favor of the early cutting of hay. Whether there are any compensating advantages in late cutting remains to be seen.

The question of the relative values of early and late cut hay is, at present, much discussed. The opinion has gained ground somewhat of late that the value of early cut hay has been over-estimated. This opinion has doubtless been strengthened by the claim that in the true grasses quite a percentage of the nitrogen in the young plant is not in the albuminoid form, and that the relative percentage of albuminoid nitrogen increases with age.

#### The Occurrence of Amides in Grass, and their Influence upon Nutritive Value.

The method which chemists have been forced to take for the estimation of albuminoids, has been based upon an assumption, viz: That, essentially all the nitrogen of plants exists in the albuminoid form. Acting on this assumption, and knowing that the average percentage of nitrogen in the various albuminoid substances is about sixteen (16) per cent. of the whole substance, it has been customary to determine the amount of nitrogen and multiply this by $6\frac{1}{4}$ in order to obtain the amount of albuminoids. Were there no nitrogenous substances in hay or other cattle foods, save albuminoids, such a method of determination would probably give quite a close approximation to correct results. Later investigations show, however, that our common fodder plants contain a variety of nitrogenous compounds, some of which are not albuminoid, either in chemical form or in properties.

This renders the analysis of cattle foods, and the discussion of their values, more complicated.

Dr. H. P. Armsby,* in connection with an investigation upon the non-albuminoid nitrogen of hay and other food stuffs, has made an admirable review of the whole question, and there is here presented a brief resumé of his very complete article, with an occasional comment.

**Kinds and Occurrence of Non-albuminoid Nitrogenous Substances.**

1. Nitrates, nitrites, and ammonia salts occur in plants, most largely in root crops. [These are in the form of mineral salts, which have no significance in connection with animal nutrition, and they have to be considered in the analysis of food stuffs.]

2. The only nitrogenous organic substances, not albuminoid, which occur in sufficient abundance in cattle foods to demand attention, are the so-called *amides*, a name applied not only to amides proper, but to other bodies closely resembling them. These substances are really organic combinations of ammonia. [Amides cannot be considered so highly organized compounds as are the albuminoids.]

**Functions of Amides in the Plant.**

1. It is pretty clearly shown that all transfer of albuminoids from one part of a plant to another is accomplished by their being transformed into amides, in which form the movement occurs, and from which albuminoids are rebuilt where new plant substance is forming. [Inasmuch as amides are soluble and easily diffusible, and as albuminoids possess neither of these properties to any great extent, there is every reason why some such transformations should occur. It is an undoubted fact that the albuminoids in the seeds of grain and hay are formed from similar substances already existing in the plant, and it seems quite probable that nitrogenous substance travels from the stalk to the seeds in the form of amides.]

2. Amides have, in certain cases, been found to constitute a reserve of nitrogenous plant food, as in the case of fodder beets which have been found to contain quite a large quantity of these compounds. In the second year's growth, these amides find their way into the stalks and leaves, and are there converted into albuminoids.

**Occurrence of Amides.**

From what has been said of the functions of amides, we should expect to find them in greater abundance in young plants, which, according to the results of the investigations of Kellner, seems to be the case. The riper the plant, the larger the proportion of albuminoid nitrogen according to Kellner.

Dr. Armsby found amides in all of twenty-one samples of coarse fodder, varying from 8.93 per cent. to 39.60 per cent. of total notrogen. [So far as can be judged from the dates of cutting, the hays from the youngest grass, do not, in Dr. Armsby's analyses, show a very much larger percentage of amides than does the later cut hay. Six samples cut before July 1 gave an average of only two per cent. more of nitrogen combined as amides than the average of twelve samples cut after that time up to as late as August 15. All the samples were cut in Connecticut and New Hampshire.]

Malt sprouts, wheat and rye bran, lupines and beans, roots, and potatoes, have all been found to contain considerable non-albuminoid nitrogen. Only a small portion of the nitrogen of cereal grains is in the amide form.

*Report of Conn. Expt. Station, 1879.

### Relation of Amides to Animal Nutrition.

It is of course important to know what is the office of amides in sustaining or building up the animal body.

1. Certain experiments *seem* to show that amides can cause an increase of flesh in the animal, but this fact cannot be fully affirmed.

2. It is more probable that amides act as a protection to prevent albuminoids from oxidizing, thus allowing more of the latter to take part in flesh formation, and so, in an indirect way, are as valuable as albuminoids.

The laws of nutrition and scientific feeding standards as experimentally determined, are in no way invalidated by the discovery of this new class of compounds in cattle food.

### Composition of Samples of Hay Grown on the Central Experimental Farm, under Different Conditions of Fertility, and Cut at Different Periods of Growth.

On the 10th of May there was applied to a few square feet of grass land a mixture of dissolved bone, muriate of potash, and sulphate of ammonia, a complete fertilizer, containing all the ingredients which any soil would be likely to need in order to grow a luxuriant crop of grass. The grass growing on the spot fertilized was almost all timothy. The general condition of the land was such as to produce about one ton and a half of timothy hay per acre, being the limestone clay so common in Centre county.

The fertilizers being applied liberally, (though but once,) the grass made very luxuriant growth, certainly more than double that of the adjoining grass where no fertilizer was applied. In rapidity of development there seemed to be very little difference, the period of bloom being reached at about the same time in the two cases. Samples of both the grass fertilized and that immediately adjoining which was not, were taken at three periods of growth, as follows,* (all pure timothy:)

1. June 6. Heads just appearing.
2. June 23. Just beginning to bloom.
3. July 5. Somewhat past full blossom.

The samples were weighed green immediately on cutting, were quickly and carefully dried, and stored in paper bags.

In the following table are given the weights of the different samples when green, and of the dry hay as analyzed, with the percentage of water dried out:

| Period of Growth. | With Fertilizers. | | | Without Fertilizers. | | |
|---|---|---|---|---|---|---|
| | *Weight of grass taken. | Weight of air dry hay. | Per cent. of water evaporated. | Weight of grass taken. | Weight of air dry hay. | Per cent. of water evaporated. |
| | grams. | grams. | | grams. | grams. | |
| First, | 598.4 | 136.5 | 77.2 | 723.4 | 188.8 | 73.9 |
| Second, | 241.5 | 79.5 | 67.1 | 295.1 | 98 7 | 66.6 |
| Third, | 151.8 | 63.3 | 58.3 | 132.7 | 57.2 | 56.9 |

* The weights of samples taken have no reference to the yields of grass in the several cases.

The hay was much drier when analyzed than it would have been if kept under ordinary conditions, having been stored in a dry room for about three months. Two facts only are to be noticed in connection with the above table, viz: (1.) The youngest samples of grass lost seventeen to

* Owing to absence on a vacation, a fourth sample was not taken when the grass was nearly ripe.

nineteen per cent. of water more than the oldest, and (2) the grass fertilized, and making the largest growth, lost the most water in every case. The relative yields of grass were not taken into account, as other investigations on that point will be reported later.

The following table shows the composition of the several samples of hay, the first column giving the water content when analyzed, the remaining columns showing the composition of the water-free substance:

| Time of cutting. | Period of Growth. | With Fertilizers. | | | | | | Without Fertilizers. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 100 parts water-free substance contained. | | | | | | 100 parts water-free substance combined. | | | | |
| | | Water. | Ash. | Albuminoids. | Crude fiber. | Other carbo-hydrates. | Fat. | Water. | Ash. | Albuminoids. | Crude fiber. | Other carbo-hydrates. | Fat. |
| | | % | % | % | % | % | % | % | % | % | % | % | % |
| June 6, | Heads just appearing, | 10.86 | 8.48 | 17.37 | 29 13 | 40 67 | 4.35 | 10.11 | 6.56 | 9.63 | 28.78 | 51.17 | 3.86 |
| June 23, | Just beginning to bloom | 7.75 | 6.41 | 11.00 | 34.33 | 45.69 | 2.57 | 7.44 | 5.32 | 6.39 | 32.51 | 53.20 | 2 58 |
| July 5, | Somewhat past full blossom, . . . . . . . . . . | 7.38 | 5.74 | 7.50 | 34.68 | 50.10 | 1.98 | 6.89 | 5.19 | 5.00 | 33.86 | 53.81 | 2.14 |

In the above tables, the albuminoids are estimated in the ordinary way, *i. e.*, by multiplying the total nitrogen by 6.25. As has before been stated, not all the nitrogen of hay exists in the albuminoid form. An estimation of the albuminoid and amide nitrogen, according to the method suggested by Dr. H. P. Armsby,* gave the results that are seen in the next table:

| Time of Cutting. | Period of Growth. | With Fertilizers. | | | | Without Fertilizers. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Total nitrogen.* | Albuminoid nitrogen.* | Amide nitrogen.* | Per cent. of total nitrogen in amide form. | Total nitrogen.* | Albuminoid nitrogen.* | Amide nitrogen.* | Per cent. of total nitrogen in amide form. |
| | | % | % | % | | % | % | % | |
| June 6, . . | Heads just appearing, . . . | 2.78 | 2.00 | 0.78 | 28.06 | 1.54 | 1.20 | 0.34 | 22.08 |
| June 23, . . . | Just beginning to bloom, . . | 1.76 | 1.34 | 0.42 | 23.86 | 1.023 | 1.835 | 0.188 | 18.38 |
| July 5, . . . | Somewhat past full blossom, | 1.20 | 0.883 | 0.317 | 26.41 | 0.801 | 0.612 | 0.189 | 23.37 |
| Average, | . . . . . . . . . . . . . . . . | 1.91 | 1.41 | 0.50 | 26.11 | 1.12 | 0.88 | 0.24 | 21.28 |

* Calculated on a water-free basis.

Considering the percentages of the various forms of nitrogen of the hay from grass not fertilized as each equal to 100, we have for the percentages of nitrogen in the hay grown with fertilizers, the following relative quantities:

| | *Without Fertilizers.* | *With Fertilizers.* |
|---|---|---|
| Total nitrogen. . . . . . . . . . . . . . . . . . . . . . | 100 | 170 |
| Albuminoid nitrogen, . . . . . . . . . . . . . . . . . . . | 100 | 160 |
| Amide nitrogen, . . . . . . . . . . . . . . . . . . . . . . | 100 | 208 |

* Report Conn. Experimental Station, 1879, p. 109.

The average percentages of total nitrogen, in the amide form, have, for the two cases, the following ratio: Without fertilizers, 100; with fertilizers, 141.

### Additional Analyses.*

Since the publication of the above, analyses have been made of four other samples of hay cut at different periods of growth. On both the Eastern and Central experimental farms experiments have been conducted for the purpose of gaining more information as to the advisability of letting grass stand much beyond the period of bloom before cutting. The samples of hay analyzed in connection with these experiments, were cut at the period of bloom, and when nearly ripe. They were pure timothy, as were the fields of grass experimented upon.

Below is given the composition of four samples, two being taken from one farm, and two from the other. They were selected in each case by taking a little hay here and there from the loads at the time of weighing, and are believed to be a fair average of the fields of grass from which they came. At the time of analysis, the hay had been stored for some time in paper bags.

| Time of Cutting. | Water. | 100 parts water-free, substance contain | | | | | Laboratory number. |
|---|---|---|---|---|---|---|---|
| | | Ash. | Protein. | Crude fiber. | Other carbohydrates. | Fat. | |
| | | % | % | % | % | % | |
| Eastern farm, June 22, in bloom, . | 9.53 | 5.03 | 8.06 | 36.89 | 47.57 | 2.48 | 9 |
| July 14, nearly ripe, . . . . . | 9.46 | 3.68 | 5.68 | 35.73 | 52.54 | 2.37 | 10 |
| Central farm, June 30, in bloom, . . | 10.27 | 4.80 | 5.83 | 37.71 | 49.39 | 2.27 | 7 |
| July 13, nearly ripe, . . . . . . . . . | 10.00 | 4.08 | 4.74 | 35.58 | 53.37 | 2.23 | 8 |

In the above table the "protein" represents the sum of the albuminoid and amide nitrogen multiplied by the factor 6.25. A determination of the albuminoid nitrogen gave the following results:

| Time of Cutting. | Per cent. of total nitrogen. | Per cent. of albuminoid nitrogen. | Per ct. of amide nitrogen. | Per cent. of total nitrogen in the amide form. |
|---|---|---|---|---|
| Eastern farm, in bloom, . | 1.289 | .942 | .347 | 26.93 |
| Nearly ripe, . . . . . . | .909 | .668 | .241 | 26.51 |
| Central farm, in bloom, . . | .933 | .691 | .242 | .25.94 |
| Nearly ripe, . . . . . . . . | .758 | .567 | .191 | .25.19 |

The analyses of the ten samples of timothy hay as stated in the previous tables, simply gives the water content, and the percentage composition of

* All that precedes was published in the college report for 1881.

the dry substance of the hay. In the following table is shown the composition of the ten samples calculated with a uniform percentage of water, such as approximates very closely to the average water content of hay as stored in barns.

| Stage of Growth. | Water. | Ash. | Total nitrogen reckoned as albuminoids. | Albuminoids. | Amides.* | Crude fiber. | Other carbo-hydrates. | Fats. | Laboratory number. |
|---|---|---|---|---|---|---|---|---|---|
| *With fertilizers.* | | | | | | | | | |
| Heads just appearing, | 12.5 | 7.42 | 15.20 | 10.94 | 4.26 | 25.49 | 35.59 | 3.80 | 1 |
| Just beginning to bloom, | 12.5 | 5.61 | 9.63 | 7.33 | 2.30 | 30.04 | 39.97 | 2.25 | 3 |
| Past full blossom, | 12.5 | 5.02 | 6.57 | 4.83 | 1.74 | 30.34 | 43.84 | 1.73 | 5 |
| *Without fertilizers.* | | | | | | | | | |
| Heads just appearing, | 12.5 | 5.74 | 8.43 | 6.56 | 1.87 | 25.18 | 44.77 | 3.38 | 2 |
| Just beginning to bloom, | 12.5 | 4.65 | 5.59 | 4.57 | 1.02 | 28.45 | 46.55 | 2.26 | 4 |
| Past full blossom, | 12.5 | 4.54 | 4.38 | 3.35 | 1.03 | 29.63 | 47.08 | 1.87 | 6 |
| In bloom, | 12.5 | 4.37 | 7.06 | 5.16 | 1.90 | 32.28 | 41.62 | 2.17 | 9 |
| Nearly ripe, | 12.5 | 3.22 | 4.97 | 3.65 | 1.32 | 31.27 | 45.97 | 2.08 | 10 |
| In bloom, | 12.5 | 4.20 | 5.10 | 3.78 | 1.32 | 33.00 | 43.19 | 2.01 | 7 |
| Nearly ripe, | 12.5 | 3.57 | 4.15 | 3.10 | 1.05 | 31.13 | 46.70 | 1.98 | 8 |

The last table gives simply the total quantities of the various ingredients in a hundred pounds of the different kinds of hay. Only certain percentages of these ingredients are digested. Moreover, the percentages that are digestible vary with the quality of the hay, the better hays being more digestible than the poorer.

The following table shows the digestion percentages that have been assumed for the various grades of hay, the figures being taken from the results of German investigation. The numbers in the left hand column refer to those given in the right hand column of the previous table.

| Laboratory Number. | Parts in one hundred digested of the various ingredients. | | | |
|---|---|---|---|---|
| | Protean. | Crude fiber. | Other carbo-hydrates. | Fat. |
| 1, 2, and 3, | 64 | 64 | 67 | 48 |
| 4, 5, 7, and 9, | 56 | 57 | 63 | 48 |
| 6, 8, and 10, | 52 | 57 | 61 | 49 |

* It should be remembered that the term "amides" is used here to represent the total non-albuminoids nitrogenous matter.

Using these percentages, we have the following quantities of digestible nutrients in one hundred pounds of the hays analyzed :

| Laboratory Number. | Protean. | Carbo-hydrates. | Fats. | Nutritive ratio. | Quality. | Time of cutting. |
|---|---|---|---|---|---|---|
| 1, . . . . . . . . . . . . | 9.72 | 40.10 | 1.82 | 1: 4.7 | Extra, . . | Heading out. |
| 3, . . . . . . . . . . . . | 6.16 | 45.98 | 1.08 | 1: 7.9 | Very good, | In early bloom. |
| 5, . . . . . . . . . . . . | 3.68 | 44.91 | 0.83 | 1:12.8 | Average, . | Past blossom. |
| 2, . . . . . . . . . . . . | 5.40 | 46.11 | 1.62 | 1: 9.3 | Good, . . | Heading out. |
| 4, . . . . . . . . . . . . | 3.13 | 45.53 | 1.08 | 1:15.4 | Average, . | In early bloom. |
| 6, . . . . . . . . . . . . | 2.28 | 45.60 | 0.92 | 1:21 | Poor, . . . | Past blossom. |
| 9, . . . . . . . . . . . . | 3.95 | 44.62 | 1.04 | 1:11.9 | Good, . . | In bloom. |
| 10, . . . . . . . . . . . | 2.58 | 45.86 | 1.02 | 1:18.8 | Poor, . . . | Nearly ripe. |
| 7, . . . . . . . . . . . . | 2.86 | 46.02 | 0.96 | 1:16.9 | Average, . | In bloom. |
| 8, . . . . . . . . . . . . | 2.16 | 46.23 | 0.97 | 1:22.5 | Poor, . . . | Nearly ripe. |

The " nutritive ratio " is the relation of the quantity of digestible nitrogenous material to the quantity of digestible carbo-hydrates, the latter including two and one half times the fats.

The extent to which hay is nitrogenous, is not only an indication of its capacity for milk and meat production, but also gives some idea as to the proper kind and amounts of bye fodder that should be fed with it. There is here inserted, for purposes of comparison, a table giving the content of total and digestible ingredients of various grades of German hays :

| | Water. | Ash. | Albuminoids. | Fiber. | Other carbo-hydrates. | Fat. | Digestible Nutrients. | | | Nutrative ratio. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Albuminoids. | Carbo-hydrates, incl. fiber. | Fat. | |
| | % | % | % | % | % | % | % | % | % | |
| Meadow hay, poor, . . . . . . . . . . . . | 14.3 | 5.0 | 7.5 | 33.5 | 38.2 | 1.5 | 3.4 | 34.9 | 0.5 | 1 : 10.6 |
| Do. fair, . . . . . . . . . . . | 14.3 | 5.4 | 9.2 | 29.2 | 39.7 | 2.0 | 4.6 | 36.4 | 0.6 | 1 : 8.3 |
| Do. medium, . . . . . . . . . . | 14.3 | 6 2 | 9.7 | 26.3 | 41.4 | 2.5 | 5.4 | 41.0 | 1.0 | 1 : 8.0 |
| Do. very good, . . . . . . . . . | 15.0 | 7.0 | 11.7 | 21.9 | 41.6 | 2.8 | 7.4 | 41.7 | 1.3 | 1 : 6 1 |
| Do. extra, . . . . . . . . . . | 16.0 | 7.7 | 13.5 | 19.3 | 40.4 | 3.0 | 9.2 | 42.8 | 1.5 | 1 : 5.1 |

### General Conclusions.

1. The hay cut at a late period of growth differs in composition from that cut at an early period, mainly in accordance with the statements previously made concerning other observations ; the late cut hay containing less nitrogen, less ash and fats, and more crude fiber and other carbo-hydrates.

The effect of this change is to render the late cut hay much less nitrogenous than early cut, and the digestibility is also less in the case of the former.

2. In the ten samples of hay analyzed, an average of 26.16 per cent. of the nitrogen was found to exist in the non-albuminoid form, and what was to the writer a somewhat surprising result, is that the later cut, even the " nearly ripe " grass, contained as large a percentage of the nitrogen in the

" amide " form as did that cut in the early stages of growth. (For remarks on correctness of results, see " Methods of Analysis.") Other analysts have reached essentially the same results.*

3. The effect of an abundant supply of plant food seems to have been the increasing of the percentage of nitrogen very largely, and also of the crude fiber to a limited extent. The hay grown under conditions of fertility, took up more mineral matters also. The fertilizers caused a somewhat larger percentage of nitrogen to exist in the amide form.

The largely increased percentage of albuminoids in the hay grown under conditions of great fertility, show that a high state of cultivation effects the production, not only of a greater quantity, but of a better quality of hay.

4. So far as composition is any indication of value, the hay from early cut grass is more valuable, pound for pound, than that from late cut grass. (See " Experiments on Feeding.") Notice that in No. 1 there is contained in one hundred pounds of hay, nearly ten pounds of digestible protein, accompanying each pound of which (digestible protein) is found the equivalent of less than five pounds of digestible carbo-hydrates. In No. 5, which is from a sample of the same grass only cut much later, one hundred pounds of hay would contain less than four pounds of digestible protein, but in this case each pound of digestible protein is accompanied by nearly thirteen pounds of digestible carbo-hydrates. Whatever may be demonstrated in the future as to the relative value of early and late cut hay, there is no sort of doubt but that as foods, the two are very *different*. (See " Experiments on Feeding.") It seems doubtful if the effect of age upon the existence of true albuminoids in grass, is a matter of so much importance as at first believed. Further investigation will decide.

**Amount and Character of the Growth of Grass subsequent to the period of Bloom**

It is not enough to know that a hundred pounds of hay made from early cut grass is more valuable than the same weight of hay from grass that is more mature. The question of the amount of yield must be considered, for it is important to know whether the increase of dry material harvested, would more than counter balance the decrease in quality, when grass is not cut until quite a late, instead of at an earlier, period. The decision of the question involves many difficulties, and a single experiment will only serve to add a few facts to the many that are needed before we can reach certain conclusions.

The experiments conducted at the Eastern and Central Farms, have been mentioned previously. At each farm, a field of two acres of as pure, and as nearly uniform timothy as could be selected, was accurately measured off, and divided into eight equal plots. In each case alternate plots were cut while in bloom, while the grass on the remaining plots stood until it was quite ripe. The hay was weighed when put in the barn, and after lying in the barn for some months, was re-weighed.

On the Central Farm the water content of the hay was determined at the time of the second weighing. The analyses of the several hays are given previously. With the data thus obtained, we are able to calculate the approximate increase of the dry substance of the hay, and we can also determine to what ingredients this increase, if any, is due :

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*See Department of Agriculture report for 1880.

| | Hay Cut in Bloom. | | | Hay Cut when Nearly Ripe. | | | Amount of increase by standing until nearly ripe. |
|---|---|---|---|---|---|---|---|
| | Eastern farm. | Central farm. | Average. | Eastern farm. | Central farm. | Average. | |
| Time of cutting, . . . . . | June 22. | June 30. | . . . . . . | July 14. | July 13. | | |
| Weight of hay when put in barn, . . . . . . | *3,634 lbs. | 5,000 lbs. | 4,317 lbs. | 4 234 lbs. | 5,270 lbs. | 4,752 lbs. | 435 lbs. |
| Weight of hay when re-weighed in winter, . | 2,307 lbs. | 3,922 lbs. | 3,115 lbs. | 3,390 lbs. | 4,035 lbs. | 3,713 lbs. | 598 lbs. |
| Decrease in weight by lying in barn, . . . | 1,327 lbs. | 1,078 lbs. | 1,202 lbs. | 844 lbs. | 1,235 lbs. | 1,039 lbs. | |
| Per cent. of decrease in weight by lying in barn, | 36.51 pr ct. | 21.56 pr ct. | 29.04 pr ct. | 19.93 pr ct. | 23.43 pr ct. | 21.68 pr ct. | |
| Amount of water — free substance, . . . . . . . | 2,031 lbs. | 3,481 lbs. | 2,756 lbs. | 2.966 lbs. | 3,581 lbs. | 3.274 lbs. | 518 lbs. |
| Amount of ash, . . . . | 101.6 lbs. | 167 lbs. | 134 3 lbs. | 109.1 lbs. | 146 lbs. | 127.6 lbs. | — 8.7 lbs. |
| Amount of protein, . . | 163 7 lbs. | 203 lbs. | 183.4 lbs. | 168 5 lbs. | 170 lbs. | 169 3 lbs. | —14.1 lbs. |
| Amount of albuminoids, | 119.6 lbs. | 150.4 lbs. | 135 lbs. | 124 lbs. | 126 6 lbs. | 125.3 lbs. | — 9.7 lbs. |
| Amount of amides, . | 44.1 lbs. | 52.6 lbs. | 48.4 lbs. | 44.5 lbs. | 43.4 lbs. | 44 lbs. | — 4.4 lbs. |
| Amount of crude fiber, . | 749 lbs. | 1,313 lbs. | 1,031 lbs. | 1,060 lbs. | 1,274 lbs. | 1,167 lbs. | 136 lbs. |
| Amount of extractive matters, . . . . . . . | 966 lbs. | 1,720 lbs. | 1,343 lbs. | 1,558 lbs. | 1,911 lbs. | 1,735 lbs. | 391 lbs. |
| Amount of fat, . . . . . . | 50 lbs. | 79 lbs. | 65 lbs. | 70 lbs. | 80 lbs. | 75 lbs. | 10 lbs. |

* The figures in the table have reference to pounds per acre.

There is a seeming decrease of mineral matter and protein in the late cut hay. This is due probably to errors, or to lack of uniformity in the fields of grass selected. At the same time the amount of decrease is not too great to have resulted from loss or decay of the finer parts of the plant, or from loss of seeds. It at least seems that there could have been no very great increase of either nitrogenous or mineral substances, but that the growth was almost entirely confined to the non-nitrogenous parts of the plant, or the parts that, for the purposes of milk or flesh production have least value. Moreover, unless future investigation proves present methods of analysis to be faulty, *the increased age of the grass did not in these cases have the effect of converting non-albuminoid nitrogen into albuminoid form.*

## Loss of Water from Hay after Storing in the Barn.

It is often the case that farmers can dispose of hay by weight at the time it is harvested. Hay usually is sold at lower rates when hauled directly from the field, than after it has been stored for some time. It is doubtful, however, if the true difference in value is generally appreciated.

It may not be amiss to present a summary of such observations as are at hand with reference to this point. While there would be more water in hay some seasons than in others, the average of quite a number of trials may serve as a pretty fair basis of estimation.

| YEAR. | Date of cutting. | Stage of growth. | Weight when put in barn. | Date of second weighing. | Weight at second weighing. | Per cent. of loss in weight. | Kind of grass. |
|---|---|---|---|---|---|---|---|
| | | | Lbs. | | Lbs. | Per ct. | |
| 1879, | July 1, . | Beginning to bloom. . | 3,444 | Winter, . | 2,760 | 19.6 | Timothy. |
| 1879, | July 11, . | Seed began to mature, . | 4,263 | Winter, . | 3,538 | 17.0 | Timothy. |
| 1880, | June 30, . | Headed out, . . . . . . | 3,035 | Winter, . | 2,351 | 22.5 | Timothy, (some clover.) |
| 1880, | July 9, . | Fall bloom, . . . . . . | 3,585 | Winter, . | 2,673 | 25.4 | Timothy. |
| 1880, | July 19, . | Seeds forming, . . . . | 4,555 | Winter, . | 3,386 | 25.6 | Timothy. |
| 1880, | July 9, . | In bloom, . . . . . . . | 3,470 | Winter, . | 2,324 | 33. | Timothy. |
| 1880, | July 19, . | Seeds forming, . . . . | 4,530 | Winter, . | 2,928 | 35.3 | Timothy. |
| 1880, | July 1, . | . . . . . . . . . . . . . | 4,875 | Winter, . | 3,600 | 26.1 | Clover mostly. |
| 1880, | July 9, . | . . . . . . . . . . . . . | 4,825 | Winter, . | 3,707 | 22.9 | Clover mostly. |
| 1879, | June 14, . | Timothy shooting. Clover full head, . . . | 800 | Dec. 31, . | 680 | 15. | Timothy and clover. |
| 1879, | June 19, . | Timothy, half blossom. Clover not half dead, | 800 | Dec. 31, . | 632 | 21. | Timothy and clover. |
| 1879, | June 24, . | Timothy, full blossom. Clover half dead, . . | 800 | Dec. 31, . | 530 | 33.8 | Timothy and clover. |
| 1879, | June 30, . | Timothy out of blossom, Clover nearly dead, . | 800 | Dec. 31, . | 704 | 12. | Timothy and clover. |
| 1881, | June 22, . | In bloom, . . . . . . . | 3,634 | Winter, . | 2,307 | 36.5 | Timothy. |
| 1881, | July 14, . | Nearly ripe, . . . . . . | 4,234 | Winter, . | 3,390 | 19.9 | Timothy. |
| 1881, | June 30, . | In bloom, . . . . . . | 5,000 | December | 3,922 | 21.6 | Timothy. |
| 1881, | July 13, . | Nearly ripe, . . . . . . | 5,270 | December | 4,035 | 23.4 | Timothy. |
| Average* loss by drying in barn, (17 trials,) . . . . . . . . . . . . | | | | | | 24.1 | |

On the basis of the above figures, hay that could be sold for ten dollars, when taken from the field, should bear a price of nearly twelve and one half dollars the following winter, provided no conditions had changed, save the weight of the hay. We can, also, get some idea of the amount of water in hay when housed. It is probably fair to assume that hay that has been lying in the barn for some time contains about 12.5 per cent., or one eighth its weight of water. If such hay is assumed to have lost 24 per cent. of its weight, since the time of storing, a little calculation shows that when taken from the field, one third (about) its weight was water. Freshly-cured hay is not generally stated to contain as much water, but other observations have been made with small samples rather than by re-weighing large quantities, and the latter method is the one more to be relied upon.

## ENSILAGE.

The work undertaken on ensilage, the results of which are contained in the following, was entered upon not to show that corn fodder can be preserved in pits, nor to demonstrate that fodder thus treated is nutritious and readily eaten, for these facts are acknowledged. The principal object of the investigation was to ascertain the extent of the changes and loss which the fodder suffers from the fermentation. It was, of course, deemed desirable to obtain accurate data as to the cost and feeding value of the fermented materials, but circumstances were such as to prevent reliable results being reached in these directions. It is hoped that the work of another year can be made more comprehensive, so as to include all the factors involved in the question of profit.

### Cultivation of the Crop.

The corn was planted the last week in May, on land producing a small crop of wheat the previous year. Manure was applied at the rate of about

* The first nine cases are taken from "Farm Experiments," by Prof. J. W. Sanbor and the next four from Pennsylvania State College Report 1879-80.

eight cords per acre. One bushel of seed was planted per acre, the variety being Southern White corn.

It was expected that the two acres of land planted would produce at least thirty tons of green fodder, but owing to the exceptionally severe drought the crop was considerably less than half that amount. The corn received about the same cultivation as ordinary field corn.

### Preservation of the Fodder by Ensilage.

In order to avoid the cost of an expensive silo, an old root cellar was made to answer every purpose. The cellar was of masonry, cemented air tight. As it was too large, a partition was thrown across midway, so that the silo was really built of masonry on three sides. and of wood on the fourth.

The fodder was cut into pieces about three quarters of an inch long, by one of Hauck & Comstock's fodder cutters,* smallest size, which was found to do efficient work, cutting the fodder at the rate of thirty tons per day. The chopped fodder was pushed through a trap-door in the barn floor into the silo below, where it was tramped down by mules. After being thoroughly tramped down the compact mass was covered with a layer of straw about eight inches deep, then two layers of boards, and upon the boards was piled stone at the rate of half a ton to every square yard. The silo was filled during the second week in September, and was not opened until December.

### Character and Appearance of the Ensilage.

When the silo was opened, it was found that at the surfaces and sides the fodder was blackened and somewhat decayed to the depth of a few inches.

The remaining portion of the very compact material was darker in color than when it was put in, had the characteristic odor and slightly acid taste noticed in all ensilage, but, on the whole, seemed to be nicely preserved. Nearly all of the animals to which it was offered, ate it at once quite heartily.

The description of the practical details of constructing and filling the silo are made brief, because they are matters about which any intelligent, reading farmer need have no lack of reliable information; and, as before stated, it is not the *possibility* of ensilage that needs discussion.

### Character and Extent of the Changes that Occur in the Fodder During Ensilage.

No one has attempted to dispute the fact that fermentation takes place in the silo to a greater or less extent, according to the manner of filling, but which no amount of care can entirely prevent. Fermentation must result in certain changes in the composition of the fodder, which must affect the nutritive value of the material fermented. The character of these changes has been better understood than their extent.

While it has been well known that the alcoholic and lactic fermentations must go on largely at the expense of the carbo-hydrates (sugar, starch, &c.,) there has been no very definite knowledge as to the quantity of these ingredients thus destroyed, or the accompanying changes experienced by other and more valuable compounds. With a view to obtaining more information on these points, the fodder that was packed in the silo was carefully weighed at the time it was cut, and several samples were also selected for analysis in such a manner as to render it quite certain that the average composition of the fodder at time of cutting would be correctly ascer-

* Purchased of Alexander & Co., Bellefonte, Pennsylvania.

tained. The ensilage as taken from the silo was also carefully weighed and sampled. It should be stated that the sampling of the ensilage was such as to exclude those portions on the surface and sides of the silo that were much decayed, all the material that was taken for analysis being such as was in the ordinary state of preservation.

TABLE I.

| | *Green fodder.* | *Ensilage.* |
|---|---|---|
| Total weight, | 22,535 pounds. | 19,116 pounds. |
| Water content, | 71.58 per cent. | 73.61 per cent.* |
| Weight of water-free substance, | 6,404 pounds. | 5,045 pounds. |
| Per cent. of water-free substance lost, | | 21.22 per cent. |

The quantity of water-free substance calculated for the ensilage is undoubtedly too small, owing to the method of sampling referred to above. The outer portions of the ensilage did not contain as much water probably as those portions taken for analysis, which would cause an error in the above method of estimating the water-free substance in the whole mass of material. A more accurate way of ascertaining the real loss from the well-preserved ensilage is based upon the fact that one part of the fodder would not be affected in quantity at all by fermentation, viz: The ash or mineral substances. The organic substances only would be decomposed and pass off, so that one pound of ash would be found in less water-free substance in the ensilage than in the corn fodder before fermentation.

The next table gives the composition of the water-free substance in the two cases.

TABLE II.

| | *Green stalks.* | *Ensilage.* |
|---|---|---|
| Ash, | 5.04 | 5.51 |
| Protein, | 6.54 | 7.18 |
| Crude fiber, | 24.22 | 27.43 |
| Other carbo-hydrates, | 62.31 | 56.98 |
| Ether extract,† | 1.89 | 2.90 |

The preceding figures show that one hundred pounds of water-free substance in the fodder as taken from the field contained 5.04 pounds of mineral matters, while owing to a destruction of other material one hundred pounds of dry material in the ensilage contained 5.51 pounds of ash. By calculation we find that 91.47 pounds of water-free substance in the ensilage contain the same quantity of ash as one hundred pounds of water-free substance in the fodder before fermentation. In other words, *the green fodder lost in the silo 8.53 pounds out of every one hundred pounds of water-free substance put in, or a loss of 8.53 per cent. of dry substance.* As 6,404 pounds of dry substance were put into the silo, the total loss of water-free material would be 546 pounds. Practically the loss is more owing to the decay on the surface and sides, but the last estimate corresponds more nearly to what is correct than do the figures given in Table I.‡

Now, upon what ingredients of the fodder does this loss fall? Knowing the percentage composition of the water-free substance in the two cases, we can calculate the amount of each class of ingredients in 100 pounds of dry substance in the corn as taken from the field, and in 91.47 pounds, as

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* Water and other volatile substances.

† Fat, chlorophyl, &c.

‡ Since beginning to write out the results given here, I have received the Second Annual Report of the New Jersey Experiment Station; also a bulletin giving results accordant with these presented here, only the investigation was much more comprehensive. It was found at the New Jersey Station that 100 pounds of dry substance lost in the silo 17¾ pounds.

found in the ensilage, the latter being what remained of each 100 pounds put into the silo.

TABLE III.

| | Green stalks. In 100 pounds of water-free substance. | Ensilage. In 91.47 pounds of water-free substance. |
|---|---|---|
| | Pounds. | Pounds. |
| Ash, . . . . . . . . . . . . . . . . . . . . | 5.04 | 5.05 |
| Protein, . . . . . . . . . . . . . . . . . . | 6.54 | 6.57 |
| Fiber, . . . . . . . . . . . . . . . . . . . | 24.22 | 25.09 |
| Other carbo-hydrates, . . . . . . . . . | 62.31 | 52.12 |
| Ether extract, . . . . . . . . . . . . . . | 1.89 | 2.65* |
| | 100.00 | 91.47 |

A glance at the above table shows that *the loss has fallen entirely upon the carbo-hydrates*, about *sixteen (16) per cent. of this class of compounds having been used up during the process of fermentation.*†

The percentages of protein in the previous tables were obtained in the usual way, by multiplying the total nitrogen by the factor 6.25. Nothing is learned in this way as to the forms of the nitrogen compounds, either in the green fodder or in the ensilage. Determinations of albuminoid and non-albuminoid nitrogen by Stutzer's method, (see methods of analysis,) gave the following results for water-free substance:

| | Green stalks. | Ensilage. |
|---|---|---|
| Total nitrogen, . . . . . . . . . . . . . . | 1.047 per cent. | 1.149 per cent. |
| Albuminoid nitrogen, . . . . . . . . . . | .914 per cent. | .567 per cent. |
| "Amide" nitrogen, . . . . . . . . . . . . | .133 per cent. | .582 per cent. |
| Per cent. of total nitrogen in the non-albuminoid form, . . . . . . . . . . . | 12.70 | 50.66 |

The above figures are the averages of closely accordant parallel determinations. While no conclusions should be drawn from them, they indicate that there may possibly be a breaking up of albuminoid compounds, at the same time that there is no actual loss of nitrogen. If such be the case the nutritive value of the fodder would probably be affected.

There follows a table showing the composition of the green corn stalks, and the same after undergoing changes in the silo:

| | Water. | Ash. | Protein. | Crude fiber. | Other carbo-hydrates. | Fats. Ether extract. |
|---|---|---|---|---|---|---|
| Green stalks, . . . . . . . . . . . | 71.58 | 1.43 | 1.86 | 6.88 | 17.71 | 0.54 |
| Ensilage, . . . . . . . . . . . . . . | 73.61 | 1.45 | 1.90 | 7.24 | 15.03 | 0.77 |

### Results of Feeding the Ensilage.

All the ensilage was fed to a herd of milch cows. Owing to utter lack of time no accurate data were obtained as to the results. It can be said,

* The ether extracted nearly six per cent. of material from the ensilage, only about one half of which was found to be soluble in benzine, and the figures given in the tables for per cent. of fat in the ensilage represent what was soluble in benzine. All the ether extract from the fodder before fermentation was found to be soluble in benzine.

† This result agrees with that arrived at by the New Jersey Experiment Station, viz: That there was no loss of nitrogen, crude fiber, or fat from the fermentation in the silo.

however, that no marked benefit could be noted by any ordinary method of observation. Previous to being fed on ensilage, the cows had been eating all the dried corn-fodder (stover) they would consume in connection with corn-meal and wheat bran. The amount of meal and bran fed was not changed, and all the ensilage was given that the animals would take; but in passing from one ration to the other there appeared to be no change either way in the amount of milk produced. As the milk was sold daily by the quart any marked decrease or increase would have been noted, especially as attention was directed to the matter. Neither is there any good reason for thinking that the milk improved in quality because of the ensilage. It is expected that more accurate observations will be made next winter on the comparative value of corn-fodder dried in the field, and the same preserved in a silo.*

### General Remarks.

One thing is certain, viz: Nothing came out of the silo that was of value, that did not go in, in an equally valuable form. It is quite absurd with our present state of knowledge to claim that green corn-fodder increases in value by being allowed to lie in a large mass and undergo a partial decomposition. It may be safely affirmed that to the extent that such decomposition goes on with any cattle food, to that extent is its capacity decreased for running or building up the animal machine. Careful investigation has also shown that fermented fodder has not an increased digestibility over unfermented, neither is there much reason why we should expect such a result. The experience of many years shows that ensilage is not a necessity for securing the healthfulness or vigor of animals, for a variety of food can be obtained more cheaply in other ways. Then why all this excitement over silos, and why call an "ensilage congress" any more than a "cotton seed meal" congress? Certainly the farmer who preserves grass in silos, and so handles three tons of water several times in order to feed his cattle one ton of dry substance, has lost his judgment, for grass can be cured to perfection by the old-fashioned method.

And as for preserving green corn-fodder, the only peg the ensilage enthusiast has to hold to, is his ability to show that by the use of the silo greater nutritive value is secured than by drying and stacking the fodder. In the careful investigation made at the New Jersey Experiment Station the results did not differ materially with the two methods, save that the expense must have been greater in the case of the ensilage.

The above is not meant for a general condemnation of ensilage, as it may have its advantages for a certain class of farmers, but there seem to be no good reasons why farmers should get excited over it, or expect from it any remarkable results.

### Methods of Analysis.

The analytical methods adopted in the execution of the analysis herewith reported, are those in common use for the determination of the proximate composition of plants. No attempt was made to determine anything more than the amounts of each of the four general classes of organic ingredients, viz: albuminoids, amides, carbo-hydrates and fats, excepting the usual estimation of crude fiber. Anything beyond this is of little use with our present knowledge of digestion and nutrition.

Determination of Nitrogen.—This was accomplished by the usual soda-lime method, both ordinary soda-lime and Johnson's being used. Some-

* It is but justice to say that such work had been planned previous to receiving the report of the investigation at the New Jersey Experiment Station.

thing more than .5 of a gram of hay was usually ignited in a tube, from fifteen to eighteen inches long. The results with the two kinds of soda-lime did not differ, only that it seemed to take a longer tube to secure complete combustion with Johnson's, than with the ordinary soda-lime. The standard solutions used were sulphuric acid and ammonia, cochineal being used as an indicator.

Determination of Albuminoid and Amide Nitrogen.—Considerable interest is attached to the method of analysis used here, more than in the case of other determinations where old, long tried, and accurate methods are at hand. So scanty, in fact, is our knowledge of the nitrogenous bodies in grass, that more or less uncertainty accompanies any method of separation of amide from albuminoid nitrogen. A very common method of separation has been to extract the hay or other substance with boiling water, generally made slightly acid with some organic acid, adding at last some precipitant to throw down any albuminoids that might be in solution. The amide nitrogen has been considered to be found wholly in the extract, and the albuminoid nitrogen, in the residue. The precipitants used have been acetate of lead, sulphate of copper, hydrate of copper, acetate of iron, carbolic acid, &c. Experiments made with known compounds have shown the results by the above general method to be reliable, when some of the precipitants at least were used.

Dr. Armsby, formerly of the Connecticut Experiment Station, made some comparative determinations* which seem to show that no precipitant is necessary in the case of hays, but that simple extraction of water acidified with lactic acid, effects complete separation of albuminoid and non-albuminoid compounds, or at least as complete as when a precipitant is used. In the separation of albuminoid and non-albuminoid nitrogen in the first six samples of hay analyzed, Dr. Armsby's modification was adopted, but as the results were unexpected, it was deemed wise in the analysis of the remaining hays to make comparative determinations with some method involving the use of a precipitant. This was done, using Stützer's method,† the precipitant being copper hydrate. The process followed, was to boil the hay, (.5 of a gram about.) in water slightly acidified with lactic acid, for three quarters of an hour, then add a sufficient amount of copper hydrate,‡ boil a few minutes longer, and filter. This differs from Dr. Armsby's method, only in the addition of copper hydrate. The nitrogen was determined in the residue after washing with hot water, and drying. The extract was in all cases filtered through a very compact asbestos filter, with the aid of a strong filter pump, and the filtrate obtained was always perfectly clear.

In igniting the extracted hay, both filter and hay were mixed with soda-lime. By using ignited asbestos for the filters no correction of the results was necessary. In order that but little asbestos should be used, the filter was constructed by plugging the upper part of the neck of an ordinary funnel, the asbestos being sustained by a plug of perforated cork. The filters were usually not more than three quarters of an inch in depth. In removing the hay from the funnel, the asbestos was pushed out by means of a small glass rod that could be inserted in the neck of the funnel, and any material that adhered closely to the funnel was wiped off with a little moistened asbestos. This method seemed to secure convenience and accuracy.

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* See report of Connecticut Experiment Station, for 1879, p. 109.

† See Beiderman's Central-blatt für Agr. Chem. Jahr. 9, Heft XII, S. 875. *Ibid*, Jahr. 10, Heft II, S. 134.

‡ For preparation of copper hydrate, see last reference.

Parallel determinations were made in all cases. Comparative results obtained with and without the use of copper hydrate are as follows:

| | No. 7. | | No. 8. | | No. 9. | | No. 10. | |
|---|---|---|---|---|---|---|---|---|
| | | % | | % | | % | | % |
| Water, | | 10.27 | | 10.00 | | 9.53 | | 9.46 |
| Total nitrogen, | .81<br>.849<br>.857 | .838 | .673<br>.674<br>.699 | .682 | 1.145<br>1.187 | 1.166 | | .823 |
| *Albuminoid nitrogen:* | | | | | | | | |
| Armsby's method, | .608<br>.632 | .62. | .518<br>.502 | .51 | .83<br>.874 | .852 | .595<br>.614 | .605 |
| Stutzer's method, | .605<br>.65 | .628 | .493<br>.517 | .505 | .858<br>.858 | .858 | .649<br>.625 | .637 |
| *Amide nitrogen:* | | | | | | | | |
| Armsby's method, | | .218 | | .172 | | .314 | | .218 |
| Stutzer's method, | | .210 | | .177 | | .308 | | .186 |
| *Per cent. total nitrogen in amide form:* | | | | | | | | |
| Armsby's method, | | 25.94 | | 25.19 | | 26.93 | | 26.51 |
| Stutzer's method, | | 25.06 | | 25.98 | | 26.46 | | 22.66 |

The results given are all that were obtained and are not selected. There seems to be no doubt that with hays the use of a precipitant for the albuminoids is unnecessary. The average percentage of nitrogen in the amide form was found to be only about one per cent. less when copper hydrate was used than when it was not, and as .01 per cent. error in the determination of the nitrogen would be enough to account for this difference, we may regard it as insignificant.

As to the absolute accuracy of either method we cannot speak with certainty. It seems more probable that the albuminoid nitrogen is less than what these analyses show than that it is greater, for the reason that it seems more likely that non-albuminoid nitrogenous compounds would remain in the extracted hay than that any albuminoids should remain in solution.

## Feeding Experiments.

Feeding trials have been made with the early and late cut hay referred to in previous pages, also with cotton seed and corn meal. At both the Eastern and Central Farms, the animals fed have been fattening steers. The trials were conducted with the utmost care, observing the methods and precautions indicated below.

At each farm for each trial, four steers were selected, two being fed after one method, and the other two after the method with which it was desired to make comparison. The steers were selected so that in each lot of four, one pair should be as nearly like the other pair in size, weight, form, general appearance and habit, as it was possible. The selection at the Central Farm of eight steers, was out of a lot of twenty-five.

The rations that it was desired to test were weighed to the animals each day, any material they did not eat being also weighed.

The weight of the steers was in no case recorded until the animals had been eating their rations for one week. The weighings were made weekly, at the same hour in the day, always before taking water. In all things except in what they ate, the steers were treated as nearly alike as possible.

### Experiments in Feeding Early and Late Cut Hay.

As before stated, one lot of hay was cut while in bloom, and the other lot when approaching ripeness. At the Eastern Farm the hay was chopped

before feeding for convenience in weighing, and was fed with a small quantity of corn meal. After feeding two steers on early cut hay and two on late cut for a period of four weeks, the rations were changed about so that those getting early cut hay during the first period of four weeks, got late cut hay for an equally long period, and those getting late cut hay at first, got early cut for the last period. Below are the results:

**Tables showing results of Experiment at the Eastern Farm.**

*First Period, (28 days.)*

| | Steers No. 1 and 2,* early cut hay. | Steers No. 3 and 4,* late cut hay. |
|---|---|---|
| Date of beginning, | Dec. 22. | Dec. 22. |
| Date of ending, | Jan. 19. | Jan. 19. |
| Weight of steers December 22, | 2,142 lbs. | 2,150 lbs. |
| Weight of steers January 19, | 2,208 lbs. | 2,158 lbs. |
| Total gain in weight, | 66 lbs. | 8 lbs. |
| Total quantity of hay eaten, | 883.5 lbs. | 816 lbs. |
| Hay eaten per day, | 31.7 lbs. | 29.1 lbs. |
| Total quantity of corn meal eaten, | 336 lbs. | 336 lbs. |
| Corn meal eaten per day, | 12 lbs. | 12 lbs. |

*Second Period, (28 days.)*

| | Steers No. 1 and 2, late cut hay. | Steers No. 3 and 4, early cut hay. |
|---|---|---|
| Date of beginning, | Jan. 26. | Jan. 26. |
| Date of ending, | Feb. 23. | Feb. 23. |
| Weight of steers January 26, | 2,230 lbs. | 2,180 lbs. |
| Weight of steers February 23, | 2,356 lbs. | 2,290 lbs. |
| Total gain in weight, | 126 lbs. | 110 lbs. |
| Total quantity of hay eaten, | 818 lbs. | 812.5 lbs. |
| Hay eaten per day, | 29.2 lbs. | 29 lbs. |
| Total quantity of corn meal eaten, | 336 lbs. | 336 lbs. |
| Corn meal eaten per day, | 12 lbs. | 12 lbs. |

The following is a summary of the two periods:

| | Early cut hay. | Late cut hay. |
|---|---|---|
| Total quantity of hay eaten, | 1,696 lbs. | 1,634 lbs. |
| Hay eaten per day, (during 56 days,) | 30.3 lbs. | 29.2 lbs. |
| Total quantity corn meal eaten, | 672 lbs. | 672 lbs. |
| Corn meal eaten per day, | 12 lbs. | 12 lbs. |
| Total gain in weight, | 176 lbs. | 134 lbs. |
| Gain of two steers per day, | 3.14 lbs. | 2.4 lbs. |
| Gain per pound of hay fed, | .104 lbs. | .082 lbs. |

Relative value of each kind of hay as per experiment, is seen to be: Early cut : late cut :: 100 : 79.

At the Central Farm, the steers were not fed at two periods, but the lots of two steers each, were fed for a while on the same ration, in order to ascertain the relative gain under similar conditions. so as to determine whether any difference in gain of weight when fed on different rations would be due to differences in the animals. The hay was not chopped, and a smaller quantity of meal was fed than at the Eastern Farm.

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*The quantities given in the tables refer to the amounts fed to two steers.

**Table Showing Result of Experiment at the Central Farm.**

| | Steers No. 1 and 2, early cut hay. | Steers No. 2 and 3, late cut hay. |
|---|---|---|
| Date of beginning, | Dec. 1. | Dec. 1. |
| Date of ending, | Feb. 25. | Feb. 25. |
| Weight of steers, December 1, | *1,750 lbs. | *1,630 lbs. |
| Weight of steers, February 25, | 1,922 lbs. | 1,702 lbs. |
| Total gain in weight, | 172 lbs. | 72 lbs. |
| Total quantity of hay eaten, | 2,924 lbs. | 2,234 lbs. |
| Hay eaten per day, (for 86 days,) | 34 lbs. | 26 lbs. |
| Total quantity of corn meal eaten, | 602 lbs. | 602 lbs. |
| Corn meal eaten per day, | 7 lbs. | 7 lbs. |
| Gain per pound of hay fed, | .059 lbs. | .032 lbs. |
| Gain of two steers per day, | 2 lbs. | .84 lbs. |

Relative value of each kind of hay as per experiment: Early cut : late cut :: 100 : 55.

The method of comparison here adopted is for the last experiment hardly fair, because of the fact of a greater quantity of early cut hay being fed than of late cut. It would be fairer perhaps to determine whether the excess of early cut hay fed is sufficient to account for the difference in gain, or whether something must be allowed for a difference in the quality of the two kinds of hay. The steers receiving early cut hay ate 690 pounds of hay more than did the others, and gained 100 pounds more, a gain of one pound for every 6.9 pounds of hay consumed. In other words, three pounds of hay added to the daily ration of a single steer caused him to gain nearly one half pound per day more than he otherwise would have done. It is possible that we need seek for no other explanation for the better gain of steers Nos. 1 and 2. It is but fair to say, however, that more early cut hay was consumed than of late cut, because of the greater palatableness of the former. In both cases all the hay was consumed that the steers would take. The steers have been sold for six and a half cents per pound, giving a value of $6 50 to the 100 pounds excess of gain. This would make the excess of hay fed worth $18 80 per ton. Certainly the profits are greater from the early cut hay compared pound for pound with the late cut, and for this the greater palatableness of the former may fairly receive credit.

As to the question of a difference in the capacities for growth of the two lots of animals, they were fed alike for a period of five weeks subsequent to the feeding on the two kinds of hay, and steers 1 and 2 gained 143 pounds, and steers 3 and 4 gained 173 pounds, showing that if either lot possessed a superior capacity for growth the advantage was with those fed on late cut hay. Let it be remembered in regard to all these results that they are the work of but a single year, and have value accordingly. So far, however, as any value attaches to the outcome of the experiments, the early cut hay has the advantage.

**Experiments in Feeding Corn Meal and Cotton Seed Meal.**

The farmers of Pennsylvania fatten annually a large number of cattle. The principal food made use of for this purpose, beside coarse fodder, is cornmeal. Some farmers feed the cornmeal nearly pure, others mix with it considerable oatmeal, wheat bran to a limited extent, cotton seed and linseed meal. Opinions differ as to what food or mixture of foods is wisest. So far we have very little but opinion, if we except the experimental work of the Germans.

Leaving the presentation of the scientific side of the question until later, it can be said that one practical inquiry is of great importance, viz: Can

* The figures given refer to food and gain of two steers.

farmers profitably purchase the highly nitrogenous cattle foods that are for sale in our markets in order to combine them with the corn and coarse fodder produced on the farm? Theories based on scientific investigation would answer the inquiry in the affirmative, so far as it is a question of proper combination of food ingredients, and so of an economical use of the material consumed. Of course the variable relative prices of these various food stuffs is something of which science can take no account, and the farmer must decide, from year to year, what he can or cannot afford to purchase. The great underlying principles in all practice in cattle feeding are those that determine the proper amounts and relation of nutrients in the ration, and these principles once understood it only remains for the farmer to purchase or produce these nutrients in the cheapest possible form.

As in the case of early and late-cut hay, experiments have been conducted at both the Eastern and Central Experimental Farms. The number of steers fed, and the precautions in feeding and weighing were the same as in the experiments on hay. A ration of corn meal and cornfodder has in each case been compared with one composed of corn meal, cotton seed meal, and cornfodder. In the latter ration the corn meal and cotton seed meal were mixed in the proportion of one hundred pounds of the former to forty pounds of the latter.

The results of the experiment at the Eastern Farm are as follows:

**Tables Showing Results of Experiment at the Eastern Farm on Feeding Fattening Steers.**

*First Period, (55 days.)*

| | Steers 5 and 6, Corn meal alone. | Steers 7 and 8, Mixture of corn meal and cotton seed. |
|---|---|---|
| Date of beginning, | December 15 | December 15 |
| Date of ending, | February 9 | February 9 |
| Weight of steers, December 15, | 2,110 lbs.* | 2,110 lbs.* |
| Weight of steers, February 9, | 2,220 lbs. | 2,336 lbs. |
| Total gain in weight, | 110 lbs. | 226 lbs. |
| Total quantity of cornfodder eaten, | 674 lbs. | 833 lbs. |
| Cornfodder eaten per day, | 12.3 lbs. | 15.1 lbs. |
| Total quantity cornmeal eaten, | 1,660 lbs. | 1,078 lbs. |
| Corn meal eaten per day, | 30.2 lbs. | 19.6 lbs. |
| Total quantity cotton seed meal eaten, | | 431 lbs. |
| Cotton seed meal eaten per day, | | 7.8 lbs. |

*Second Period, (42 days.)*

| | Steers 5 and 6. Mixture of corn meal and cotton seed. | Steers 7 and 8. Corn meal alone. |
|---|---|---|
| Date of beginning, | Feb. 16. | Feb. 16. |
| Date of ending, | March 30. | March 30. |
| Weight of steers February 16, | 2,254 pounds. | 2,368 pounds. |
| Weight of steers March 30, | 2,404 pounds. | 1,510 pounds. |
| Total gain in weight, | 120 pounds. | 152 pounds. |
| Total quantity of cornfodder eaten, | 419 pounds. | 524 pounds. |
| Cornfodder eaten per day, | 10 pounds. | 12.5 pounds. |
| Total quantity of corn meal eaten, | 830 pounds. | 1,245 pounds. |
| Corn meal eaten per day, | 19.8 pounds. | 29.7 pounds. |
| Total quantity cotton seed eaten, | 333 pounds. | |
| Cotton seed eaten per day, | 7.9 pounds. | |

A summary of the two periods shows the results to be as follows:

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*All the weights given in these tables refer to two steers.

| | Corn meal alone. | Mixture of corn meal and cotton seed. |
|---|---|---|
| Total quantity cornfodder eaten, . . . . | 1,198 pounds. | 1,252 pounds. |
| Cornfodder eaten per day, (97 days,) . . | 12.3 pounds. | 13 pounds. |
| Total quantity corn meal eaten, . . . . . | 2,905 pounds. | 1,908 pounds. |
| Corn meal eaten per day, . . . . . . . . | 30 pounds. | 19.7 pounds. |
| Total quantity cotton seed eaten, . . . . | . . . . . . | 764 pounds. |
| Cotton seed eaten per day, . . . . . . . | . . . . . . | 7.9 pounds. |
| Total gain in weight, . . . . . . . . . . | 262 pounds. | 376 pounds. |
| Cost of food,* . . . . . . . . . . . . | $46 57 | $47 04 |
| Cost of food per pound of increase, . . . | 17.7 cents. | 12.5 cents. |

The superintendent of the Eastern Farm states in his report that steers five and six were inferior in growing capacity to steers seven and eight. During the "first period," when the former lot was fed on the corn meal ration, their gain was very unsatisfactory, and much inferior to the gain of steers seven and eight that ate the mixture containing cotton seed. When, however, the rations were changed about so that the poorer steers received the cotton seed and corn meal, their increase in weight was equal to that of the better lot of steers that was given pure corn meal.

The next table shows the results of the experiment at the Central Farm.

**Table Showing Results of Experiment at Central Farm in Feeding Fattening Steers.**

| | Steers No. 5 and 6, corn meal alone. | Steers No. 7 and 8, mixture of corn meal and cottom seed. |
|---|---|---|
| Date of beginning, . . . . . . . . . . . . . . . | Jan. 7. | Jan. 7. |
| Date of ending, . . . . . . . . . . . | April 1. | April 1. |
| Weight of steers, January 7, . . . . . . . . . | 1,835 lbs. | 1,939 lbs. |
| Weight of steers, April 1, . . . . . . . . . . . | 2,010 lbs. | 2,200 lbs. |
| Total gain in weight, . . . . . . . . . . . | 175 lbs. | 261 lbs. |
| Total quantity of cornfodder eaten, . . . . | 840 lbs. | 1,436 lbs. |
| Cornfodder eaten per day, (84 days,) . . . . | 10 lbs. | 17 lbs. |
| Total quantity of corn meal eaten, . . . . . . | 2.626 lbs. | 1,344 lbs. |
| Corn meal eaten per day, . . . . . . . . . | 31.3 lbs. | 16 lbs. |
| Total quantity of cotton seed eaten, . . . . . . . . | . . . . . | 672 lbs. |
| Cotton seed eaten per day, . . . . . . . . . | . . . . . . . . | 8 lbs. |
| Cost of food, . . . . . . . . . . . . . | $43 37 | $38 15 |
| Cost of ration per day, . . . . . . . . . . . . | 0 52½ | 0 45 8/10 |

In this case the rations were not changed about, so as to give the mixture of corn meal and cotton seed to Nos. 5 and 6. But in order to determine the amount of error introduced by the different capacities for growth of the two lots of animals, the steers were fed alike for four weeks previous to beginning the experimental rations. Steers Nos. 5 and 6, gained 135 pounds during the four weeks, and steers Nos. 7 and 8, gained 194 pounds, or the two lots gained in the ratio of 100 to 144. While the experimental rations were fed, the gain of steers 5 and 6, was to the gain of steers 7 and 8, as 100 to 149. Or the relative gain of the two lots was the same when fed alike, and when fed the rations that were put to a comparative test. Now one lot ate about 32 pounds of corn meal per day, and the other lot only 16 pounds of corn meal, and 8 pounds of cotton seed; that is, 1 pound of cotton seed when combined with the other foods was able to replace 2 pounds of corn meal.

The superintendents of both farms report themselves as favorably impressed by the practical results of adding cotton seed meal to the ration of the steers that were being fattened. Looked at from the stand-point of profit, the outcome with the particular animals fed, and with relative prices as they are at present, was favorable to the use of the cotton seed.

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* In estimating the cost of the food, the fodder is valued at $5 per ton, the meal at one and one half cents per pound, and the cotton seed at $40 per ton.

### The Scientific Side of Cattle Feeding.

To show that with the particular circumstances and conditions involved in the experiments here reported, one method of feeding was productive of more satisfactory results than another, would amount to very little. Like circumstances and conditions may never occur again at the college farms or elsewhere. The relative supply of cattle foods and their relative prices change from year to year.

To establish a fact with regard to the laws of animal nutrition, or some principle involved in all practice, would be to secure a lasting benefit. We need not so much to know that under certain conditions of practice certain results follow as to know the reasons why, or the principles involved. For instance, granting that a mixture of corn meal and cotton seed as fed in these experiments produced as much growth as a larger amount of pure corn meal, this may not be true simply because cotton seed and corn meal were fed together, but because the mixture furnished a more efficient combination of food ingredients than was the case with corn meal alone. It may be a question of the economical use by the animal organism of certain quantities of protein and carbo-hydrates mixed in certain proportions rather than of cattle foods having certain names. If this be true, then we are not shut up to corn meal and cotton seed as the only means of securing the desirable combination, but can use any cattle foods that will furnish the ingredients we desire in the proper quantities and proportions. It must be remembered that protein, for instance, is a constituent of all cattle foods, and that it may be of more importance that we give an animal a certain quantity of it in a digestible form accompanied by proper amounts of other compounds, than that we supply it in any particular kind of food, whether it be hay, corn meal, wheat bran, or cotton seed. From the data given on previous pages, let us see what were the real differences between the rations fed in the experiments reported.

### Composition of the Various Food Stuffs used.

The composition of the hays fed can be seen on previous pages. The composition of the corn fodder, corn meal, and cotton seed, can be safely assumed from the average of a number of analyses of these food stuffs. No analyses were made of the particular samples used, because of entire lack of time.

| | Water. | Ash. | Protein. | Crude fiber. | Other carbo-hydrates. | Fats. |
|---|---|---|---|---|---|---|
| | % | % | % | % | % | % |
| Corn fodder, (stover,)* . . . . . . . . | 15 | 4.2 | 3 | 40 | 36.7 | 1 |
| Corn meal, (Dent corn,) av. 19 analyses | 11.13 | 1.48 | 10.49 | 1.86 | 70.20 | 4.84 |
| Cotton seed meal,† decorticated, av. 3 analyses, . . . . . . . . . . . | 7.70 | 7.04 | 42.79 | 6.36 | 19.76 | 16.35 |

The above table shows, that if a hundred pounds of cotton seed be fed to an animal, there would be given 42.79 pounds of protein. Not all of this protein could be used, as only a certain percentage of it would be digested. A cattle food is valuable, not because of what it contains, but be-

* From Mentzel u. Lengerke's landw. Kalender, 1882.

† The sample fed was a fine one, procured from Alexander & Co., Bellefonte, Pa.

cause of what can be digested from it. Very careful and elaborate investigation has shown that, with the exception of roots, no ingredient of any cattle food is ever completely digested. Moreover, by a large amount of experimenting, it has been ascertained what are the approximate percentages of the constituents of the various foods that are digested, these digestion coefficients varying with the kind and quality of the fodder. The following table shows those applying to corn fodder, corn meal, and cotton seed :

| | Protein. | Crude fiber. | Other carbo-hydrates. | Fats. |
|---|---|---|---|---|
| Corn fodder,* | 37 | ..... | ..... | 30 |
| Corn meal,† | 79 | 62 | 91 | 85 |
| Cotton seed meal, (decorticated,)‡ | 85 | ..... | 95 | 88 |

By multiplying the total quantities of the several ingredients of the cattle foods, with which we are dealing, by the percentages given in the last table, we get the following results for the percentages of *digestible nutrients.* The figures previously given for the hay, are brought forward for the sake of convenience.

| Laboratory number. | | IN 100 PARTS DRY SUBSTANCE THERE ARE DIGESTED OF | | |
|---|---|---|---|---|
| | | Protein. | Carbo-hydrates. | Fats. |
| | Corn fodder, | 1.1 | §37 | .3 |
| | Corn meal, | 8.33 | 65 | 4.11 |
| | Cotton seed meal, | 36.37 | 18.77 | 14.38 |
| 9 | Timothy hay, | 3.95 | 44.62 | 1.04 |
| 10 | Timothy hay, | 2.58 | 45.86 | 1.02 |
| 7 | Timothy hay, | 2.86 | 46.02 | .96 |
| 8 | Timothy hay, | 2.16 | 46.23 | .97 |

*The digestion coefficient of the "crude fiber" and "other carbo-hydrates" are not given, for it has been found that in coarse fodder, what is digested out of both of these is about equal to the total quantity of carbo-hydrates, excluding the crude fiber, or what is given in the table as "other carbo-hydrates."

† From averages given in Armsby's Manual of cattle feeding.

‡ From Biederman's Centralblatt Jahr. 10, page 32.

§ The figures in this column equal the sum of the digestible crude fiber and other carbo-hydrates.

We are now prepared to calculate the quantities of digestible nutrients actually consumed by the steers when fed on the experimental rations.

**Early and Late Cut Hay.**

| Kind and Quantity of Ration Fed a Single Animal. | Total dry matter, lbs. | Digestible. | | | Nutritive ratio. |
|---|---|---|---|---|---|
| | | Protein, lbs. | Carbo-hydrates, lbs. | Fat, lbs. | |
| *Eastern Farm.* | | | | | |
| 1. Early cut hay, (No. 9,) . . . . 15.2 lbs. | 13.3 | .60 | 6.78 | .16 | |
| Corn meal, . . . . . . . . . . . 6 lbs. | 5.34 | .50 | 3.9 | .25 | |
| Total, . . . . . . . . . . . . . . . . | 18.64 | 1.10 | 10.68 | .41 | 1 : 10.6 |
| 2. Late cut hay, (No. 10,) . . . . 14.6 lbs. | 12.8 | .38 | 6.70 | .15 | |
| Corn meal, . . . . . . . . . . . 6 lbs. | 5.34 | .50 | 3.9 | .25 | |
| Total, . . . . . . . . . . . . . . . . | 18.14 | .88 | 10.60 | .40 | 1 : 13.2 |
| *Central Farm.* | | | | | |
| 3. Early cut hay, (No. 7,) . . . . 17 lbs. | 14.9 | .49 | 7.82 | .16 | |
| Corn meal, . . . . . . . . . . . 3.5 lbs. | 3.11 | .29 | 2.27 | .15 | |
| Total, . . . . . . . . . . . . . . . . | 18.01 | .78 | 10.09 | .31 | 1 : 13.9 |
| 4. Late cut hay, (No. 8,) . . . . 13 lbs. | 11.4 | .28 | 6.00 | .13 | |
| Corn meal, . . . . . . . . . . 3.5 lbs. | 3.11 | .29 | 2.27 | .15 | |
| Total, . . . . . . . . . . . . . . . . | 14.51 | .57 | 8.27 | .28 | 1 : 15.8 |

**Corn Meal and Cotton Seed Meal.**

| Kind and Quantity of Ration Fed a Single Animal. | | Total dry matter, lbs. | Digestible | | | Nutritive ratio. |
|---|---|---|---|---|---|---|
| | | | Protein, lbs. | Carbo-hydrates, lbs. | Fat, lbs. | |
| *Eastern Farm.* | | | | | | |
| 5. Cornfodder, | 6.2 lbs., | 5.27 | .07 | 2.29 | .02 | |
| Corn meal, | 15 lbs., | 13.34 | 1.25 | 9.75 | .62 | |
| Total, | | 18.59 | 1.32 | 12.04 | .64 | 1:10.3 |
| 6. Cornfodder, | 6.5 lbs., | 5.52 | .072 | 2.40 | .02 | |
| Corn meal, | 9.9 lbs., | 8.80 | .72 | 6.44 | .41 | |
| Cotton seed meal, | 4 lbs., | 3 60 | 1.46 | .75 | .58 | |
| Total, | | 18.01 | 2.25 | 9.59 | 1.01 | 1: 5.4 |
| *Central Farm.* | | | | | | |
| 7. Cornfodder, | 5 lbs., | 4.25 | .06 | 1.85 | .02 | |
| Corn meal, | 15.7 lbs., | 14.0 | 1.31 | 10.2 | .64 | |
| Total, | | 18.25 | 1.37 | 12.05 | .66 | 1:10. |
| 8. Cornfodder, | 8.5 lbs., | 7.03 | .09 | 3.14 | .03 | |
| Corn meal, | 8 lbs., | 7.11 | .67 | 5.20 | .33 | |
| Cotton seed meal, | 4 lbs., | 3.69 | 1.46 | 0.75 | .58 | |
| Total, | | 17.83 | 2.22 | 9.09 | .94 | 1: 5.1 |

In another table let us place together the total quantities of digestible nutrients fed per day and per animal to each of the eight lots of steers, as shown in the two previous tables; also the nutritive ratios and the gain per day, so that we may discover, if possible, what the relation is between gain and food.

| | Total dry matter. | Digestible. | | | Nutritive ratio. | Grain per day.* |
|---|---|---|---|---|---|---|
| | | Protein, lbs. | Carbo-hydrates, lbs. | Fat, lbs. | | |
| | Lbs. | Lbs. | Lbs. | Lbs. | | Lbs. |
| 1. Ration containing early cut hay, | 18.64 | 1.10 | 10.68 | .41 | 1:10.6 | 1.57 |
| 2. Ration containing late cut hay, | 18.14 | .88 | 10.60 | .40 | 1:13.2 | 1.20 |
| 3. Ration containing early cut hay, | 18.01 | .77 | 10.09 | .31 | 1:13.9 | 1.0 |
| 4. Ration containing late cut hay, | 14.51 | .57 | 8.27 | .28 | 1:15.8 | 0.42 |
| 5. Corn meal without cotton seed, | 18.59 | 1.32 | 12.04 | .64 | 1:10.3 | 1.35 |
| 6. Corn meal with cotton seed, | 18.01 | 2.25 | 9.59 | 1.01 | 1: 5.4 | 1.95 |
| 7. Corn meal without cotton seed, | 18.25 | 1.37 | 12.05 | .66 | 1:10 | 1.04 |
| 8. Corn meal with cotton seed, | 17.83 | 2.22 | 9.09 | .94 | 1: 5.1 | 1.55 |
| The German standard, per 1,000 pounds live weight, | 26.0 | 2.5 | 15.0 | 0.50 | 1: 6.5 | |

* These figures refer to the gain of single animals weighing throughout the experiments an average of about a thousand pounds, the first two lots weighing a little less, and the last two a little more.

One main and important difference to be noted in the above rations, is the relation between the quantity of digestible protein, and of the digestible carbo-hydrates. It is seen that in rations six and eight, there is only the equivalent of a little over five pounds of digestible carbo-hydrates to each pound of digestible protein, while in rations two, three, and four, the ratio is very different, the digestible carbo-hydrates being present in nearly three times as large a relative quantity. Not only the relative but the absolute quantities of digestible nutrients differ very much in the various methods of feeding in the experiments, in one ration there being only about 0.6 pounds of digestible protein, and in others as much as 2.25 pounds. The variations in the amounts of digestible carbo-hydrates are very much less. It remains for future investigation to determine whether the increase in gain, that in these experiments has accompanied an increase of nitrogenous material in the food, is accidental or not. All present well-substantied theories indicate that production, whether of meat, milk, or work, is largely dependent upon the so-called protein of the food, and that the relation in amount of this protein to the amount of other nutrients determines largely the profits of feeding. The position taken is, that if too little nitrogenous material is contained in the combination of food stuffs used, it would be necessary to feed more than the animals could possibly consume in order to furnish sufficient protein to do the desired work, while if the ration be too highly nitrogenous, a waste of material occurs, and the animal fails to use the nutrients given for the purposes of growth or production of milk. In the rations discussed here there is in no case, probably, an excess of protein, while in some cases it seems as if there was a deficiency.

We believe that the question of the use of the nitrogenous waste products, offered for sale in our markets, is one of great importance. It would be well for farmers to consider whether they cannot often realize a greater profit by purchasing these and selling the products of the farm, than by feeding the latter.